

A Rule-based approach to representing en-route trajectories in ATC Directives using XML and XML Schema

**For the
Target Generation Facility
(TGF)**

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1.0 Introduction

The Simulation Group at the Target Generation Facility (TGF) continues to develop a versatile simulation tool for exploring aircraft behavior in the National Air Space (NAS).

A guiding principle in the development of the tool is use open-source, standards-based, and royalty-free tools and technologies. This results in a product that is easily ported across many hardware platforms without commercial licensing issues.

This paper describes a project, which may have implications far beyond the simulation environment, for encoding ATC (Air Traffic Control) Directives in a rule-based structure. This effort has focused on representing ATC Directives for en-route trajectories.

Consistent with the TGF development guidelines, the ATC Directives are encoded using XML (Extensible Markup Language) tags. XML Schema Language files have been developed also to define the syntax and content constraints of the XML-encoded ATC Directives.

ATC Directives are formal procedures that Air Traffic Controllers must follow when directing aircraft in their assigned sectors. They often concern unusual transfers of control, and sometime trajectory specifications, for aircraft crossing boundaries between certain sectors. In the absence of ATC Directives, Air Traffic Controllers direct aircraft along requested routes, usually defined by a flight plan, and coordinate boundary crossings to neighboring sectors with the respective Air Traffic Controllers at their own discretion with consideration of pilot requests.

Having ATC Directives encoded in a rule-based structure will help enhance the NAS simulation environment in several ways. They can be triggered when a simulated aircraft is recognized to match the criteria of the directive. Once triggered, the directive could be displayed to the SimPilot. The triggered directive could also be engaged to adjust the trajectory of the simulated aircraft directly, allowing the simulation to have an unmanned sector. Trajectory predictors consistent with ATC Directives could be implemented.

Beyond simulation, the electronic encoding of ATC directives may evolve into the standard form of directives. This could revolutionize information management of ATC Directives, with benefits to operations, administration, and training. Further, the consistence of directives could be evaluated: it could be determined if any two directives conflict with each other or if the directives in different sectors regarding the same flight trajectory agree about the handoff procedures.

2.0 Representing Data in XML

The XML markup language is a subset of a widely used international text processing standard, SGML (Standard Generalized Markup Language, ISO 8879:1986(E). Its features have been designed for ease of use as well as interoperability with both SGML and HTML. The XML specifications were developed by the World Wide Web Consortium (W3C), an organization that issues its standards as Recommendations. The current specification is defined by the document, Extensible Markup Language (XML) 1.0 (Second Edition), W3C Recommendation 6 October 2000, and can be found at <http://www.w3.org/TR/REC-xml>.

Using XML as the format for data in any application can be a powerful device for documenting the meaning of data items and can facilitate the interchange of data between programs written at different times on different platforms in different languages. Furthermore, data expressed in XML can be visually inspected with any text viewer.

The choice of XML tag names is up to the designer, and sometimes people with experience in other tagged environments, like HTML, find the freedom bewildering. In HTML, the meaning of tags is determined by their interpretation by sophisticated web browser applications. The designer's job is simply to apply the tags to achieve a desired effect in web browser applications.

With XML, choosing tag names requires an anticipation of application(s) that will be using the data. This is really no "harder" than deciding what fields will be in a record format for an application.

3.0 Representing ATC Directives in XML

3.1 Sources of ATC Directives

There are two major sources of ATC Directives for en-route trajectories. One is the Letters of Agreement (LOAs) which are agreements between controller groups that do not share a common management; for example, different ARTCCs, different Areas within an ARTCC, a Control Tower and an Area.

The other is Facilities Operations Manual of each of the 21¹ Air Route Traffic Control Centers (ARTCCs).

The Facilities Operations Manual² for the Atlanta ARTCC was available and the TGF group anticipated a project involving Atlanta, so this became the source of the initial efforts to encode ATC Directives.

3.2 XML Tags for Modeling NAS Elements

The challenge of representing ATC Directives in XML is in choosing tag names that are meaningful and in structuring the tags to faithfully represent the content of the directives. Inherent in this effort is the modeling of pertinent National Air Space (NAS) elements.

There have been several efforts to model NAS resulting in large taxonomies of objects and attributes. Notable among these is the MITRE/CAASD Automation and Visualization of Letters of Agreement and Standard Operating Procedures Information Book³ and the FAA's User Request Evaluation Tool (URET) Core Capability Limited Deployment system.

This effort began by considering whether to use these taxonomies as a starting point for XML tags. However, the task of writing a rule-based XML tag structure based on these objects seemed too hard to do. The difficulties included an overwhelming level of detail and insufficient roadmap through the relationships between objects. Further, there was concern that an effort begun from these objects could be difficult to use effectively to encode ATC Directives.

Rather than start with a pre-existing model of NAS objects and attributes, this effort began by reading the text of a Facility Operations Manual and noting informally which

¹ See list in Appendix C, page 43

² April 20, 2000

³ September 2001, by Richard Golden, Danijela Hajnal, Carl Hill-Popper, Jay Mistry, Patricia Liquori, and Francis Sutton

elements were commonly mentioned in describing Directives. These elements became names of XML tags.

4.0 XML Schema for ATC Directives

XML Schema (also called XSD) is a language specification for defining the structure, content and semantics of XML documents. XML Schema was approved as a W3C Recommendation on 2 May 2001, and the current specification can be found at <http://www.w3.org/TR/xmlschema-1/> and <http://www.w3.org/TR/xmlschema-2/>.

A schema file was developed in conjunction with the XML data file for ATC Directives to both define and enforce the structure of the XML data. The schema file has grown in significance and is an important product of the effort. In fact, the schema file may become the cornerstone of other efforts such as automation of the encoding of ATC Directives.

5.0 Rule Based Structure

5.1 Tiny Primer on Rule Based Systems

Rule based systems arose as an artificial intelligence approach to representing discrete bodies of knowledge. The idea was that if a program understood component rules governing the behavior of a domain, the program could look at the implications of the whole collection of rules and “learn” something novel. For example, the rules of geometric relations for triangles could be used to explore possible proofs of theorems or to discover if there was any way to support the truth of a geometric proposition. Or, a rule base of the legal chess moves could be used to discover the best move in a chess game by a chess-playing program. A custom manufacturing rule base could define dependencies among possible options, to the effect that if a certain component is desired, then several other components must also be included, and certain other components cannot also be in the final product. Such a rule base could be used to guide coherent ordering and production.

A rule has a condition matching part used to identify when the rule applies to a situation. A rule also has a consequence part, describing what should happen when the rule applies. When rules are used by a program, rules that first apply to starting conditions are said to “fire” or “become active”. The consequences of the rules may result in a conclusion or may just provide the next stage for considering what other rules may now apply. In a chess-playing domain, the first rules may just be all the possible legal moves that can be considered in the next move, with the consequences being the changed position of each move on the chess board. A chess-playing program may evaluate each changed board position and pick the most favorable one, deciding to make the corresponding move. (And, of course, not make all the other possible moves!) A geometry theorem prover would start from initial given conditions, consider the application of each known theorem or axiom to the given, and “assert” the one that seems to make progress toward the theorem being proven.

5.2 ATC Rule-base

The ATC Directives are encoded using a rule-base paradigm. Each directive is a rule with a “trigger” part and a “consequences” part. The trigger part is composed of a list of characteristics identifying circumstances when the directive applies. For example, that the aircraft is a turboprop or turbojet and is on V54 entering the Salem sector. The consequences part defines what happens when a directive is “triggered”, i.e., the elements of the trigger part have occurred. For example, the aircraft shall be directed to FL240.

Sometimes the main consequence of a directive is a change of aircraft trajectory. The subsequent location of the aircraft as a consequence of the “firing” and implementation of

a rule may satisfy the requirements of another rulem which may prescribe the next segment of the aircraft trajectory.

5.3 Tiny Primer on ATC Elements

The authors of ATC Directives presume an understanding of basic elements of the ATC domain.

The National Air Space (NAS) is divided into 21 Air Route Traffic Control Centers (ARTCCs). The ARTCC names and 3 letter codes are in Appendix C.

Each ARTCC is divided into Sectors, which are volumes of airspace which delimit the responsibility of one or more Air Traffic Controllers. Sectors are referred to by name, such as Salem, La Grange, Pulaski, etc., and also by number. For administrative purposes, the Sectors are grouped into Areas, usually referred to by number, e.g., 1, 2, 3, etc.

Directives generally concern which Sector controls and aircraft depending on the aircraft's location and direction. Directives sometimes proscribe the choices a controller has in directing the aircraft, e.g., mandating an altitude. The broad presumption is that the aircraft has a flight plan which depends on traffic conditions in the sectors through which it flies, and checks in with the respective controller to get permission to execute the part of the flight plan in a sector. The controller generally has discretion to modify the trajectory of the aircraft subject to traffic: generally he must maintain a 5 nautical mile (nm) horizontal separation between aircraft and either a 1000 foot or 2000 foot vertical separation, depending on altitude.

Directives often concern Sector boundaries where control is transferred.

Other elements referred to in directives include airport names, fix names, Jet-routes, Victor-routes, and Standard Arrival Routes (STARs).

6.0 Development Lessons

6.1 Start from Text of ATC Directives

The approach used to develop XML tags to describe features of ATC Directives was to start from the actual text of the ATC Directives and use the words of the directives directly. For example, in ZTL Facilities Operations, Area 1, Salem Sector, section 42 7-1-3 “Procedures a. Radar Arrival Routes”, item (4) says:

*Arrivals to the Nashville Terminal Area (BNA, MQY, JWN, MBT)
which enter or overfly the Salem Sector shall cross the Salem/Burne
boundary at or below FL310 traffic permitting.*

The word, “shall”, seems to be the predominant verb used in formal descriptions of directives. In this case, “shall” divides the “trigger” part from the “consequences” part of the directive. In the trigger part, “Arrivals to the Nashville Terminal Area...” defines a list of airports as part of the criteria of the directive. The XML rule tag for this is “<inbound-to-apt>” with child tags of “<airport-list>” and sub-children, “<airport-name>” used to identify particular airports. Two other tags, “<in-sector>” and “<above-sector>” both with values “Salem” complete the trigger part for this directive.

The consequence of this rule is defined by a “<cross>” tag and a “<AOB>”, for “at or below”, tag. The specification of the boundary being crossed has many variations; see page 38 in Appendix B for the details.

The final “traffic permitting” part of this directive is probably implied for all directives. Authors of ATC Directives presume that the reader understands the basic elements of the ATC/NAS domain but sometimes differ in how much detail is necessary in specifying a directive.

6.2 Precise Expressiveness

The task of encoding more ATC Directives in any such environment presents at least three prospects:

- 1 The expressiveness of the environment is inadequate to capture the whole meaning of the directive,
- 2 It allows expression of the whole meaning in a unique manner (i.e., two people would arrive at the same encoding of the same directive)
- 3 There are multiple ways of expressing the meaning.

By starting from the text of actual ATC Directives, it is more likely that we have achieved the second (and most desirable) of these prospects.

ATC directives in the Atlanta ARTCC Facilities Operations manual are written in a variety of styles. This complicates the approach since the same kind of directive may be described in quite different wording from one area to another. As more ATC directives are considered, the XML tags already decided are tested to see if they can capture the meaning of the directive. An informal translation of wording to XML tags often takes place. Sometimes, the encoding of another directive suggests or requires new tags and new structure.

For example, when a directive appears as part of the Facility Operations chapter for a particular sector, the first assumption was that the directive applied to aircraft IN the sector. So all the directives appearing in the chapter for, say, the Macon sector, had a trigger element, “in-sector” set to “Macon”. Later, it was noticed that there were directives mentioned in a sector chapter in which the aircraft was about to enter the sector from an adjacent sector. For these directives, the tags, “to-sector” and “from-sector”, were created. And directives were examined more carefully before automatically being labeled “in-sector” just because they appeared in a particular sector chapter.

Some directives involved several sectors and have proven difficult challenges to represent completely. (Each rule contains the original text of the directive so that the trigger and consequence parts can be reviewed for fidelity.) Multiple sectors occur in directives concerning flight paths that graze the corner of a sector and are in that sector for too short a time for the ordinary transfer of control to be done. The directives describe a handoff sequence from an initial sector through a middle “grazed” sector to a final sector. Usually, the consequences have to do with timing of handoffs, but sometimes there are contingent altitude specifications also.

Other challenging directives apply when the aircraft’s flight plan goes through one of several sectors, rather than a single specific sector. The tags for “to-sector” now can specify either a single “sector-name” or a “one-of” list of sector-names.

6.3 Postpone Issues of Meaning

While this approach provides high fidelity and unique encoding of specific ATC Directives, it does little to address the issue of different levels of detail across a group of ATC Directives. Two different directives written at different levels of detail about the same aircraft flight situation may end up with different trigger tags and may be hard to recognize as equivalent or at least comparable. This can occur when the aircraft trajectory crosses an area as well as sector boundary, concerns both sectors, but is written by two different authors (responsible for directives in their respective areas).

This issue arises because the encoding of the ATC Directives is not “forced” into a “standard” format, but follows exactly as possible the level of abstraction specified in the ATC Directive.

The choice of the project has been to postpone issues concerning meaning and levels of abstraction and let applications that use the XML data deal with it.

7.0 Trigger and Consequence Elements in XML Schema

A rule must have a trigger and a consequence part. The trigger part of a rule must have at least one of the trigger elements discussed in the first section below. The consequence part must have at least one of the consequence elements discussed in the following section. If an aircraft and it's altitude, location, and direction correspond to all the trigger parts of a rule, the consequence part of that rule should be applied to the aircraft.

7.1 XML Schema Syntax Primer

It is common to use “xsd:” as a XML Schema namespace identifier before keywords of the XML Schema language, e.g. “xsd:element”.

A Schema “element” has either a “name” attribute or a “ref” attribute. The use of the “ref=some-name” attribute means that the element *and its type* are defined somewhere else in the Schema file with a “<xsd:element name=some-name” entry. An element with a “name” attribute must also specify the type of the element, either directly or via a “type=TypeName” attribute. In the latter case, there is a type definition somewhere else in the Schema file such as <xsd:simpleType name="AircraftType">.

The naming convention used here is to specify element names with lower-case letters using a dash (-) between segments of the name, e.g., departing-from-airport and above-sector. Type names are specified without dashes using a “HumpBack” syntax in which name segments are capitalized, e.g. SectorName and AirportType.

7.2 Trigger Elements

Below is a list of all the component elements that the trigger of a rule can have, taken directly from the XML Schema file for ATC Directives (see Appendix B for a complete listing of the XML Schema). Each element is introduced by its XML Schema specification and followed by a brief discussion of typical values or usage in defining the trigger part of a rule.

```
<xsd:element ref='aircraft-type' />
```

‘aircraft-type’ is sometimes specified as “turboprop” or “turbojet”

```
<xsd:element name='in-sector' type="SectorName" />
```

‘in-sector’ means that the aircraft is in the named airspace volume.

The sector name must correspond to some name in the list

“SectorName” in the XML Schema file. See page 37 in Appendix B

```
<xsd:element name='above-sector' type="SectorName" />
```

‘above-sector’ means that the aircraft is above the named airspace volume.

```
<xsd:element name='inbound-to-apt' type="AirportType"/>
    'inbound-to-apt' means the aircraft is inbound to an airport or
    one of a list of airports, and the 3-letter airport codes must correspond
    to the codes in the list AirportType in the XML Schema file.
```

```
<xsd:element name='departing-from-apt' type="AirportType"/>
    'departing-from-apt' means the aircraft is departing from an airport
    or from one of a list of airports.
```

```
<xsd:element name='AOA-alt' type="AltitudeType"/>
    'AOA-alt' means the aircraft is at or above a specified Altitude. Valid
    values include entities of the form, FL240. See page 37 in Appendix B.
```

```
<xsd:element name='AOB-alt' type="AltitudeType"/>
    'AOB-alt' means the aircraft is at or below a specified
    altitude. Valid values include entities of the form, FL240.
```

```
<xsd:element name='from-sector' type="SectorName"/>
    'from-sector' means that the aircraft is coming from the named
    airspace volume.
```

```
<xsd:element ref='to-sector' />
    'to-sector' means that the aircraft is going to the named
    airspace volume.
```

```
<xsd:element name='to-center' type="CenterName"/>
    'to-center' means that the aircraft is going to the named Air Route Traffic
    Control Center (ARTCC). The center name must correspond to a 3-letter
    code in the CenterName list in the XML Schema. See page 38.
```

```
<xsd:element name='via-sector' type="SectorName"/>
    'via-sector' means that the aircraft is traveling via the named
    airspace volume.
```

```
<xsd:element ref='cross' />
    'cross' begins a specification of a boundary that the aircraft is crossing.
    The boundary may be a sector-boundary with sub-elements defining the
    sectors involved, or it may be a line-specification defined by two fixes, or
    a fix and an offset distance, or an arc. (See page 38 in Appendix B). It is
    also possible but not required to specify an altitude that further narrows
    the specification.
```

```
<xsd:element ref='at' />
    'at' begins a specification of location in terms of either a boundary, a
    reference point, or a region. The boundary specification is identical to that
    used in 'cross'. In specifying a region, it is possible to define the region as
    a direction relative to a 'boundary' where 'boundary' again is the same as
```

in ‘cross’ above. A region, for example, might be an area south of a boundary defined by two fixes.

```
<xsd:element name='on-Vroute' type="VRouteNames"/>  
‘on-Vroute’ provides a way to say that an aircraft is on a certain Victor route.
```

```
<xsd:element ref='flight-plan-request'/>  
‘flight-plan-request’ is part of a specification of an aircraft’s requested flight in a sector. Example components include altitude and whether the request is to be above or below this altitude.
```

```
<xsd:element name='transition' type="FixName"/>  
‘transition’ means a fix name identifying the beginning of a descent route.
```

```
<xsd:element name="direction-of-flight" type="geo-relation-type"/>  
‘direction-of-flight’ can take values of compass points like “north”, “east”, etc. that characterize the general bearing of an aircraft’s trajectory.
```

7.3 Consequence Elements

Below is a list of all the component elements that the consequence part of a rule can have, taken directly from the XML Schema file for ATC Directives (see Appendix B for a complete listing of the XML Schema). Each element is introduced by its XML Schema specification and followed by a brief discussion of typical values or usage in defining the consequence part of a rule. If a rule is triggered by a match between its trigger elements and an aircraft and it's altitude, location, and direction, the consequence parts of that rule should be applied to the aircraft.

```
<xsd:element ref='cross' />
‘cross’ begins a specification of a boundary that the aircraft is crossing.
The boundary may be a sector-boundary with sub-elements defining the
sectors involved, or it may be a line-specification defined by two fixes, or
a fix and an offset distance, or an arc. (See page 38 in Appendix B). Very
often, an altitude specification accompanies a ‘cross’ part of a
consequence. For example, “cross the Logen/North Departure boundary at
or below FL230”.
```

```
<xsd:element name='cleared-via' type="xsd:string" />
‘cleared-via’ all specification of a Standard Arrival Route (STAR).
```

```
<xsd:element ref='move-to-alt' />
‘move-to’alt’ is used to specify that an aircraft should fly at the stated
altitude.
```

```
<xsd:element ref='set-data-block' />
‘set-data-block’ is used in complicated directives where a flight parameter,
such as altitude, will ultimately be determined in a subsequent sector, and
the current controller is directed to set an initial altitude specification for
an aircraft in a data-block accessible by controllers in the subsequent
sector.
```

```
<xsd:element ref='heading' />
‘heading’ is used to specify a very specific trajectory involving two
boundaries. For example, “shall be placed on a heading that will intercept
the SPA059 radial prior to the Leeon/Moped sector boundary”. Both
boundaries are defined using the same ‘boundary’ specification used in
‘cross’ and ‘at’.
```

```
<xsd:element ref='handoff' />
‘handoff’ identifies the name of a sector to which control of an aircraft is
transferred.
```

```
<xsd:element name='transition' type="FixName" />
```

‘transition’ specifies a fix name identifying the beginning of a descent route.

```
<xsd:element ref='after-handoff-accepted' />
```

‘after-handoff-accepted’ begins the specification of elements transferred to a sector which has accepted a handoff. Typically, these element include communications and flight plan information.

8.0 Examples of ATC Directives and Corresponding XML Rule Representation

Below are examples of encoding ATC Directives into Trigger and Consequence XML tags. The ATC Directives come from the Atlanta ARTCC Standard Operations Manual of April 20, 2000. (The code for the Atlanta ARTCC is ZTL).

8.1 Example 1

The document reference is:

ZTL SOP Area 3 Macon Sector 22, 10-4-3. Procedures a. Mandatory Routing/Altitude Requirements (2)

The text of the directive is:

Aircraft entering the Burne Sector from the Macon Sector shall be assigned westbound altitudes: FL240, FL260, FL280, FL310. Aircraft entering the Macon Sector from the Burne Sector shall be assigned eastbound altitudes: FL250, FL270, FL290, FL330.

Here is the XML for the above directive:

```
<rule id="2">
  <doc-ref>
    <docref-id>22_2</docref-id>
    <docref-text>
      ZTL SOP Area 3 Macon Sector 22 10-4-3. Procedures a.
      Mandatory Routing/Altitude Requirements (2)
    </docref-text>
    <doc-text>
      Aircraft entering the Burne Sector from the Macon Sector
      shall be assigned westbound altitudes: FL240, FL260,
      FL280, FL310. Aircraft entering the Macon Sector from the
      Burne Sector shall be assigned eastbound altitudes:
      FL250, FL270, FL290, FL330.
    </doc-text>
    <sector>Macon</sector>
    <area>3</area>
    <center>ZTL</center>
  </doc-ref>
  <trigger>
    <in-sector>Macon</in-sector>
    <from-sector>Burne</from-sector>
  </trigger>
  <consequence>
    <move-to-alt>
      <one-of>
```

```
<altitude>FL250</altitude>
<altitude>FL270</altitude>
<altitude>FL290</altitude>
<altitude>FL330</altitude>
</one-of>
</move-to-alt>
</consequence>
</rule>
```

8.2 Example 2

The document reference is:

ZTL SOP Area 3 Macon Sector 22, 10-4-3. Procedures a. Mandatory Routing/Altitude Requirements (3)

The text of the directive is:

Aircraft landing Greer (GSP) overflying the Macon Sector shall cross the Macon/Spartanburg boundary at or below FL270.

Here is the XML for the above directive:

```
<rule id="3">
  <doc-ref>
    <doctitle>ZTL SOP Area 3 Macon Sector 22 10-4-3. Procedures a. Mandatory Routing/Altitude Requirements (3)</doctitle>
    <doc-text>
      Aircraft landing Greer (GSP) overflying the Macon Sector shall cross the Macon/Spartanburg boundary at or below FL270.
    </doc-text>
    <sector>Macon</sector>
    <area>3</area>
    <center>ZTL</center>
  </doc-ref>
  <trigger>
    <above-sector>Macon</above-sector>
    <inbound-to-apt>
      <airport-name>GSP</airport-name>
    </inbound-to-apt>
  </trigger>
  <consequence>
    <cross>
      <boundary>
        <sector-boundary>
          <from-sector>Macon</from-sector>
          <to-sector>Spartanburg</to-sector>
        </sector-boundary>
      </boundary>
    </cross>
  </consequence>
</rule>
```

Encoding en-route trajectory ATC Directives in XML with XML Schema

```
</boundary>
<AOB-alt>FL270</AOB-alt>
</cross>
</consequence>
</rule>
```

9.0 Applications of Rule-Based ATC Directives

Here are several ideas for using XML encoded, Rule-Based ATC Directives.

9.1 Automated Parsing of ATC Directives

This framework for representing ATC Directives as XML rules could be the core of an application that reads electronic text from Letters of Agreement or Facilities Operations Manuals and encodes the material as XML tags. Much work needs be done before the framework is mature enough. We will know that the framework is “ready” when the encoding of ATC Directives from a variety of sources can be done without revising the structure of XML tags.

Automating the directives in this manor would have substantial implications for automating the operations of other kinds of operations.

9.2 Enhancement of NAS Simulation

Once the ATC Directives have been encoded for a given airspace, it’s possible that they can be used in the TGF Simulation of activity in that airspace to enhance the fidelity of routing decisions made in that environment. This could mean that aircraft are directed by an automated Air Traffic Control operation along trajectories consistent with applicable ATC Directives, or the SimPilots could be advised by applicable ATC Directives discerned by the simulation environment.

9.3 Validation of ATC Directives

Once encoded as XML Rules, an application could be developed to assess whether any of the rules were in conflict with each other. This could happen if the rules represented directives from several sources, some of which superceded others. An example of rules in conflict is two rules that apply to the same aircraft/situation but require that the aircraft to do two mutually exclusive actions, e.g. go to FL240 and go to FL270.

10.0 Conclusion

Encoding ATC Directives in a rule-based format offers great promise. Much work needs to be done: as more Directives are encoded and the XML tags adjusted, work will be needed to establish an equivalence metric, a sequence description for Directives crossing several sectors, and a abstraction framework for machine comprehension of how the domain of one rule interacts with another.

Appendix A Code Listing of ATC Directives encoded as XML Rules

```
<?xml version="1.0" ?>
<!--  <?xml-stylesheet type="text/xsl" href="enrt13.xsl"?>  -->
<!-- enrt16.xml      12-4-2003   D. Kerr  -->
<ATC_Directives
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="file:///C:/tgf/xml/enrt/enrt16.xsd">

<rule id="1">
  <doc-ref>
    <docref-id>42_1</docref-id>
    <docref-text>
      ZTL SOP Area 1 Salem Sector 42 7-1-3. Procedures a. Radar Arrival Routes (3)
    </docref-text>
    <doc-text>
      CLT (Charlotte Douglas Airport) turbojet arrivals from the Burne Sector shall cross the common sector boundary at or below FL330 and 5 miles in-trail regardless of altitude, and when traffic permits, turbojet arrivals shall cross the common sector boundary at or below FL290 and 5 miles in-trail. All arrivals, either filed or red routed to CLT via the VXV transition, shall be on the transition, unless prior coordination is accomplished.
    </doc-text>
    <sector>Salem</sector>
    <area>1</area>
    <center>ZTL</center>
  </doc-ref>
  <trigger>
    <aircraft-type>
      <name>Turbojet</name>
    </aircraft-type>
    <inbound-to-apt>
      <airport-name>CLT</airport-name>
    </inbound-to-apt>
    <from-sector>Burne</from-sector>
  </trigger>
  <consequence>
    <cross>
      <boundary>
        <sector-boundary>
          <from-sector>Burne</from-sector>
          <to-sector>Salem</to-sector>
        </sector-boundary>
      </boundary>
      <AOB-alt>FL330</AOB-alt>
    </cross>
  </consequence>
</rule>
```

```
<rule id="2">
  <doc-ref>
    <docref-id>42_2</docref-id>
    <docref-text>
      ZTL SOP Area 1 Salem Sector 42 7-1-3. Procedures a. Radar
      Arrival Routes (4)
    </docref-text>
    <doc-text>
      Arrivals to the Nashville Terminal Area (BNA, MQY, JWN,
      MBT) which enter or overfly the Salem Sector shall
      cross the Salem/Burne boundary at or below FL310
      traffic permitting.
    </doc-text>
    <sector>Salem</sector>
    <area>1</area>
    <center>ZTL</center>
  </doc-ref>
  <trigger>
    <in-sector>Salem</in-sector>
    <above-sector>Salem</above-sector>
    <inbound-to-apt>
      <airport-list>
        <airport-name>BNA</airport-name>
        <airport-name>MQY</airport-name>
        <airport-name>JWN</airport-name>
        <airport-name>MBT</airport-name>
      </airport-list>
    </inbound-to-apt>
    <!-- Nashville Terminal Area -->
  </trigger>
  <consequence>
    <cross>
      <boundary>
        <sector-boundary>
          <from-sector>Salem</from-sector>
          <to-sector>Burne</to-sector>
        </sector-boundary>
      </boundary>
      <AOB-alt>FL310</AOB-alt>
    </cross>
  </consequence>
</rule>

<rule id="3">
  <doc-ref>
    <docref-id>43_1</docref-id>
    <docref-text>
      ZTL SOP Area 1 Pulaski Sector 43. 7-2-3. Procedures. a. Radar
      Arrival Routes. (1)
    </docref-text>
    <doc-text>
```

Turbojet arrivals to CLT and CLT satellite airports shall
be cleared via the SHINE STAR with the following
restrictions.

(a) HMV transition.

1. Turbojets shall cross 10 DME south of HMV at FL240 on the JMV transition.

2. Radar handoff and communications transfer to the Shine Sector to be completed by HMV VORTAC.

(b) VXV transition.

1. Turbojets shall cross 60 DME east of VXV at FL 240 on the VXV transition.

2. Radar handoff and communications transfer to the Shine Sector to be completed by 60 DME east of VXV.

```
</doc-text>
<sector>Pulaski</sector>
<area>1</area>
<center>ZTL</center>
</doc-ref>
<trigger>
  <aircraft-type>
    <name>Turbojet</name>
  </aircraft-type>
  <in-sector>Pulaski</in-sector>
  <inbound-to-apt>
    <airport-name>CLT</airport-name>
  </inbound-to-apt>
  <transition>HMV</transition>
</trigger>
<consequence>
  <cleared-via>SHINE STAR</cleared-via>
  <cross>
    <boundary>
      <line-specification>
        <reference-point>HMV</reference-point>
        <geo-relation-to>south</geo-relation-to>
        <distance-from>10 DME</distance-from>
      </line-specification>
    </boundary>
    <cross-alt>FL240</cross-alt>
  </cross>
  <transition>JMV</transition>
</consequence>
</rule>

<rule id="4">
  <doc-ref>
    <docref-id>43_2</docref-id>
    <docref-text>
      ZTL SOP Area 1 Pulaski Sector 43. 7-2-3. Procedures. a.
      Radar Arrival Routes. (1)
    </docref-text>
    <doc-text>
```

Turbojet arrivals to CLT and CLT satellite airports shall be cleared via the SHINE STAR with the following

restrictions.

(a) HMV transition.

1. Turbojets shall cross 10 DME south of HMV at FL240 on the JMV transition.
2. Radar handoff and communications transfer to the Shine Sector to be completed by HMV VORTAC.

(b) VXV transition.

1. Turbojets shall cross 60 DME east of VXV at FL 240 on the VXV transition.
2. Radar handoff and communications transfer to the Shine Sector to be completed by 60 DME east of VXV.

```
</doc-text>
<sector>Pulaski</sector>
<area>1</area>
<center>ZTL</center>
</doc-ref>
<trigger>
  <aircraft-type>
    <name>Turbojet</name>
  </aircraft-type>
  <in-sector>Pulaski</in-sector>
  <inbound-to-apt>
    <airport-name>CLT</airport-name>
  </inbound-to-apt>
  <transition>VXV</transition>
</trigger>
<consequence>
  <cleared-via>SHINE STAR</cleared-via>
  <cross>
    <boundary>
      <line-specification>
        <reference-point>VXV</reference-point>
        <geo-relation-to>east</geo-relation-to>
        <distance-from>60 DME</distance-from>
      </line-specification>
    </boundary>
    <cross-alt>FL240</cross-alt>
  </cross>
  <transition>VXV</transition>
</consequence>
</rule>

<rule id="5">
  <doc-ref>
    <doctitle>29_1</doctitle>
    <doctext>
      ZTL SOP Area 2 Leeon Sector 29. 8-2-3. Procedures. a.
      Mandatory Headings.
    </doctext>
  </doc-ref>
</rule>
```

Turbojet and turboprop aircraft inbound to GSP, GMU, SPA and GYH at or above 13,000 feet shall be placed on a heading that will intercept the SPA059 radial prior to the Leeon/Moped sector boundary.

```
</doc-text>
<sector>Leeon</sector>
<area>2</area>
<center>ZTL</center>
</doc-ref>
<trigger>
  <aircraft-type>
    <one-of>
      <name>Turbojet</name>
      <name>Turboprop</name>
    </one-of>
  </aircraft-type>
  <in-sector>Leeon</in-sector>
  <inbound-to-apt>
    <airport-list>
      <airport-name>GSP</airport-name>
      <airport-name>GMU</airport-name>
      <airport-name>SPA</airport-name>
      <airport-name>GYH</airport-name>
    </airport-list>
  </inbound-to-apt>
  <AOA-alt>13,000 feet</AOA-alt>
</trigger>
<consequence>
  <heading>
    <cross>
      <boundary>
        <radial-specification>
          <reference-point>SPA</reference-point>
          <bearing>59</bearing>
        </radial-specification>
      </boundary>
    </cross>
    <prior-to>
      <boundary>
        <sector-boundary>
          <from-sector>Leeon</from-sector>
          <to-sector>Moped</to-sector>
        </sector-boundary>
      </boundary>
    </prior-to>
  </heading>
</consequence>
</rule>

<rule id="6">
  <doc-ref>
    <docref-id>29_2</docref-id>
    <docref-text>
      ZTL SOP Area 2 Leeon Sector 29. 8-2-3. Procedures. d.
      Mandatory Altitudes.
    </docref-text>
  <doc-text>
```

Arrivals to the Lynchburg Regional Airport (LYH), Virginia, shall cross the ZTL/ZDC common center boundary at or below FL210 and handoff to the ZDC South Boston (SBV) Low Sector.

```
</doc-text>
<sector>Leeon</sector>
<area>2</area>
<center>ZTL</center>
</doc-ref>
<trigger>
  <in-sector>Leeon</in-sector>
  <inbound-to-apt>
    <airport-name>LYH</airport-name>
  </inbound-to-apt>
</trigger>
<consequence>
  <cross>
    <boundary>
      <center-boundary>
        <from-center>ZTL</from-center>
        <to-center>ZDC</to-center>
      </center-boundary>
    </boundary>
    <AOB-alt>FL210</AOB-alt>
  </cross>
  <handoff>
    <sector>South Boston</sector>
  </handoff>
</consequence>
<comment>Lynchburg Regional Airport (LYH), Virginia</comment>
</rule>

<rule id="7">
  <doc-ref>
    <docref-id>32_1</docref-id>
    <docref-text>
      ZTL SOP Area 2 Spartanburg High Sector 32. 8-5-3.
      Procedures. a. Radar Arrival Routes.
    </docref-text>
    <doc-text>
      Turboprop and turbojet aircraft inbound to GSO/INT shall
      be cleared via Brook 2 Arrival GSO/INT. These aircraft
      shall cross 30 miles northeast of SPA at FL240.
    </doc-text>
    <sector>Spartanburg High</sector>
    <area>2</area>
    <center>ZTL</center>
  </doc-ref>
  <trigger>
    <aircraft-type>
      <one-of>
        <name>Turbojet</name>
        <name>Turboprop</name>
      </one-of>
    </aircraft-type>
    <in-sector>Spartanburg High</in-sector>
    <inbound-to-apt>
```

```
<airport-list>
    <airport-name>GSO</airport-name>
    <airport-name>INT</airport-name>
</airport-list>
</inbound-to-apt>
    <!-- (GSO is Greensboro, SC; INT is Winston-Salem, NC) -->
</trigger>
<consequence>
    <cleared-via>Brook 2 Arrival GSO/INT</cleared-via>
    <cross>
        <boundary>
            <line-specification>
                <reference-point>SPA</reference-point>
                <geo-relation-to>northeast</geo-relation-to>
                <distance-from>30 miles</distance-from>
            </line-specification>
        </boundary>
        <cross-alt>FL240</cross-alt>
    </cross>
</consequence>
</rule>

<rule id="8">
    <doc-ref>
        <docref-id>15_1</docref-id>
        <docref-text>
            ZTL SOP Area 3 Baden Sector 15. 9-1-3. Procedures. b.
            Mandatory Altitude Requirements. (1) To Lanier Sector.
            (a)
        </docref-text>
        <doc-text>
            (1) To Lanier Sector.
            (a) All aircraft landing in the Atlanta Terminal Area
            shall be cleared to cross the 50 nm arc of ODF at
            FL350.
        </doc-text>
        <sector>Baden</sector>
        <area>3</area>
        <center>ZTL</center>
    </doc-ref>
    <trigger>
        <in-sector>Baden</in-sector>
        <inbound-to-apt>
            <airport-group>Atlanta Terminal Area</airport-group>
        </inbound-to-apt>
        <via-sector>Lanier</via-sector>
    </trigger>
    <consequence>
        <cross>
            <boundary>
                <arc-specification>
                    <reference-point>ODF</reference-point>
                    <distance-from>50 nm</distance-from>
                </arc-specification>
            </boundary>
            <cross-alt>FL350</cross-alt>
        </cross>
    </consequence>
</rule>
```

```
</consequence>
</rule>

<rule id="9">
<doc-ref>
<docref-id>15_2</docref-id>
<docref-text>
    ZTL SOP Area 3 Baden Sector 15. 9-1-3. Procedures. b.
    Mandatory Altitude Requirements.(1) To Lanier Sector. (b)
</docref-text>
<doc-text>
    (1) To Lanier Sector.
        (b) arrivals to the Nashville Terminal Area (BNA, MQY,
            JWN, MBT) shall be descended to FL350 and handed off to
            Lanier Sector in sufficient time for the aircraft to
            cross the Lanier/Burne boundary at or below FL310.
</doc-text>
<sector>Baden</sector>
<area>3</area>
<center>ZTL</center>
</doc-ref>
<trigger>
<in-sector>Baden</in-sector>
<inbound-to-apt>
    <airport-list>
        <airport-name>BNA</airport-name>
        <airport-name>MQY</airport-name>
        <airport-name>JWN</airport-name>
        <airport-name>MBT</airport-name>
    </airport-list>
</inbound-to-apt>    <!-- Nashville Terminal Area -->
<via-sector>Lanier</via-sector>
</trigger>
<consequence>
<move-to-alt>
    <altitude>FL350</altitude>
</move-to-alt>
<handoff>
    <sector>Lanier</sector>
</handoff>
<cross>
    <boundary>
        <sector-boundary>
            <from-sector>Lanier</from-sector>
            <to-sector>Burne</to-sector>
        </sector-boundary>
    </boundary>
    <AOB-alt>FL310</AOB-alt>
</cross>
</consequence>
</rule>

<rule id="10">
<doc-ref>
<docref-id>15_3</docref-id>
<docref-text>
```

Encoding en-route trajectory ATC Directives in XML with XML Schema

```
ZTL SOP Area 3 Baden Sector 15. 9-1-3. Procedures. b.  
Mandatory Altitude Requirements.(1) To Salem Sector  
</docref-text>  
<doc-text>  
To Salem Sector. Arrivals to the Nashville Terminal Area  
(BNA, MQY, JWN, MBT) shall be descended to FL350 and  
handed off to the Salem Sector in sufficient time for the  
aircraft to cross the Salem/Burne boundary at or below  
FL310.  
</doc-text>  
<sector>Baden</sector>  
<area>3</area>  
<center>ZTL</center>  
</doc-ref>  
<trigger>  
  <in-sector>Baden</in-sector>  
  <inbound-to-apt>  
    <airport-list>  
      <airport-name>BNA</airport-name>  
      <airport-name>MQY</airport-name>  
      <airport-name>JWN</airport-name>  
      <airport-name>MBT</airport-name>  
    </airport-list>  
    </inbound-to-apt>  <!-- Nashville Terminal Area -->  
  <via-sector>Salem</via-sector>  
</trigger>  
<consequence>  
  <move-to-alt>  
    <altitude>FL350</altitude>  
  </move-to-alt>  
  <handoff>  
    <sector>Salem</sector>  
  </handoff>  
  <cross>  
    <boundary>  
      <sector-boundary>  
        <from-sector>Salem</from-sector>  
        <to-sector>Burne</to-sector>  
      </sector-boundary>  
    </boundary>  
    <AOB-alt>FL310</AOB-alt>  
  </cross>  
</consequence>  
<comment>  
The Salem Sector is directly below the Baden Sector; the  
boundary between Burne Sector and Salem Sector is the same  
as the boundary between Burne and Baden  
</comment>  
</rule>  
  
<rule id="11">  
  <doc-ref>  
    <docref-id>49_1</docref-id>  
    <docref-text>  
      ZTL SOP Area 3 Logen Sector 49. 9-5-3. Procedures. c.  
      Mandatory Altitude Requirements.(2) To North Departure  
    </docref-text>
```

```
<doc-text>
    Arrivals to Chattanooga (CHA) north of the Foothills
    VORTAC (ODF) shall enter the North Departure Sector at or
    below FL120.
</doc-text>
<sector>Logen</sector>
<area>3</area>
<center>ZTL</center>
</doc-ref>
<trigger>
    <in-sector>Logen</in-sector>
    <inbound-to-apt>
        <airport-name>CHA</airport-name>
    </inbound-to-apt>
    <at>
        <boundary>
            <line-specification>
                <reference-point>ODF</reference-point>
                <geo-relation-to>north</geo-relation-to>
            </line-specification>
        </boundary>
    </at>
</trigger>
<consequence>
    <cross>
        <boundary>
            <sector-boundary>
                <from-sector>Logen</from-sector>
                <to-sector>North Departure</to-sector>
            </sector-boundary>
        </boundary>
        <AOB-alt>FL120</AOB-alt>
    </cross>
</consequence>
</rule>

<rule id="12">
    <doc-ref>
        <docref-id>49_2</docref-id>
        <docref-text>
            ZTL SOP Area 3 Logen Sector 49. 9-5-3. Procedures. c.
            Mandatory Altitude Requirements.(3) From North Departure
            (a)
        </docref-text>
        <doc-text>
            Aircraft crossing the Logen/North Departure boundary on
            or north of V54 at or above 11,000 feet, inbound to GVL
            or AJR, shall cross the boundary descending to or at
            11,000 feet and handed off to Logen.
        </doc-text>
        <sector>Logen</sector>
        <area>3</area>
        <center>ZTL</center>
    </doc-ref>
    <trigger>
        <in-sector>North Departure</in-sector>
        <inbound-to-apt>
```

```
<airport-list>
    <airport-name>GVL</airport-name>
    <airport-name>AJR</airport-name>
</airport-list>
</inbound-to-apt>
<AOA-alt>11,000 feet</AOA-alt>
<on-Vroute>V54</on-Vroute>
<cross>
    <boundary>
        <sector-boundary>
            <from-sector>Logen</from-sector>
            <to-sector>North Departure</to-sector>
        </sector-boundary>
    </boundary>
</cross>
<at>
    <region-specification>
        <boundary>
            <VRoute>V54</VRoute>
        </boundary>
        <geo-relation-to>north</geo-relation-to>
    </region-specification>
</at>
</trigger>
<consequence>
    <cross>
        <boundary>
            <sector-boundary>
                <from-sector>North Departure</from-sector>
                <to-sector>Logen</to-sector>
            </sector-boundary>
        </boundary>
        <AOA-alt>11,000 feet</AOA-alt>
    </cross>
    <handoff>
        <sector>Logen</sector>
    </handoff>
</consequence>
<comment>
    This is about aircraft entering Logen from North Departure;
    so this rule should start out with the aircraft IN North
    Departure, crossing into Logen...
</comment>
</rule>

<rule id="13">
    <doc-ref>
        <docref-id>49_3</docref-id>
        <docref-text>
            ZTL SOP Area 3 Logen Sector 49. 9-5-3. Procedures. c.
            Mandatory Altitude Requirements.(3) From North Departure
            (b)
        </docref-text>
        <doc-text>
            Aircraft crossing the Commerce/Logen/North Departure
            boundary south of V54 inbound to GVL or AJR, shall cross
            the Commerce/North Departure boundary at or below 7,000
        </doc-text>
    </doc-ref>
</rule>
```

```
feet.
</doc-text>
<sector>Logen</sector>
<area>3</area>
<center>ZTL</center>
</doc-ref>
<trigger>
  <in-sector>Logen</in-sector>
  <inbound-to-apt>
    <airport-list>
      <airport-name>GVL</airport-name>
      <airport-name>AJR</airport-name>
    </airport-list>
  </inbound-to-apt>
  <cross>
    <boundary>
      <sector-boundary>
        <from-sector>North Departure</from-sector>
        <to-sector>Logen</to-sector>
      </sector-boundary>
    </boundary>
  </cross>
  <at>
    <region-specification>
      <boundary>
        <VRoute>V54</VRoute>
      </boundary>
      <geo-relation-to>south</geo-relation-to>
    </region-specification>
  </at>
  <from-sector>North Departure</from-sector>
</trigger>
<consequence>
  <cross>
    <boundary>
      <sector-boundary>
        <from-sector>North Departure</from-sector>
        <to-sector>Commerce</to-sector>
      </sector-boundary>
    </boundary>
    <AOB-alt>7,000 feet</AOB-alt>
  </cross>
</consequence>
<comment>Commerce Sector is directly below the Logen Sector;
the boundary between North Departure Sector and Commerce is
the same as the boundary between North Departure and Logen...
</comment>
</rule>

<rule id="14">
  <doc-ref>
    <docref-id>49_4</docref-id>
    <docref-text>

      ZTL SOP Area 3 Logen Sector 49. 9-5-3. Procedures. c.
      Mandatory Altitude Requirements.(3) From North Departure
      (c)
    </docref-text>
  </doc-ref>
</rule>
```

```
</docref-text>
<doc-text>
    Atlanta Terminal Area departures to TRI or AVL,
    requesting FL240 or higher, shall be assigned FL230 as a
    final altitude.
</doc-text>
<sector>Logen</sector>
<area>3</area>
<center>ZTL</center>
</doc-ref>
<trigger>
    <in-sector>Logen</in-sector>
    <departing-from-apt>
        <airport-group>Atlanta Terminal Area</airport-group>
    </departing-from-apt>
    <inbound-to-apt>
        <airport-list>
            <airport-name>TRI</airport-name>
            <airport-name>AVL</airport-name>
        </airport-list>
    </inbound-to-apt>
    <flight-plan-request>
        <altitude>FL240</altitude>
        <alt-relation-to>aoa</alt-relation-to>
    </flight-plan-request>
</trigger>
<consequence>
    <move-to-alt>
        <altitude>FL230</altitude>
    </move-to-alt>
</consequence>
</rule>

<rule id="15">
    <doc-ref>
        <docref-id>49_5</docref-id>
        <docref-text>
            ZTL SOP Area 3 Logen Sector 49. 9-5-3. Procedures. c.
            Mandatory Altitude Requirements. (3) From North Departure
            (d)
        </docref-text>
        <doc-text>
            Arrivals to WDR, AHN, or 19A, south of HRS, shall cross
            the Logen/North Departure boundary at or below FL230,
            descending to 11,000 and handed off to Logen.
        </doc-text>
        <sector>Logen</sector>
        <area>3</area>
        <center>ZTL</center>
    </doc-ref>
    <trigger>
        <in-sector>North Departure</in-sector>
        <inbound-to-apt>
            <airport-list>
                <airport-name>WDR</airport-name>
                <airport-name>AHN</airport-name>
            </airport-list>
        </inbound-to-apt>
    </trigger>
</rule>
```

```
        <airport-name>19A</airport-name>
    </airport-list>
</inbound-to-apt>
<at>
    <boundary>
        <line-specification>
            <reference-point>HRS</reference-point>
            <geo-relation-to>south</geo-relation-to>
        </line-specification>
    </boundary>
</at>
</trigger>
<consequence>
    <cross>
        <boundary>
            <sector-boundary>
                <from-sector>North Departure</from-sector>
                <to-sector>Logen</to-sector>
            </sector-boundary>
        </boundary>
        <AOB-alt>FL230</AOB-alt>
    </cross>
    <move-to-alt>
        <altitude>11,000 feet</altitude>
    </move-to-alt>
    <handoff>
        <sector>Logen</sector>
    </handoff>
</consequence>
</rule>

<rule_issues id="12">
    <comment>
        This rule concerns aircraft entering a sector, not leaving
        it!
    </comment>
</rule_issues>

<rule_issues id="15">
    <comment>
        Consequence altitude may be a flight plane descent
        description but may also just be ambiguous.
    </comment>
</rule_issues>

</ATC_Directives>
```

Appendix B Code Listing of the XML Schema for ATC Directives

```

<?xml version="1.0" ?>
<!-- enrt16.xsd      12-4-2003  D. Kerr  -->

<!--      added trigger element "to-sector"      -->
<!--      added SectorNames Macon, Macon High, South Departure, Clark
Hill      -->
<!--      added second reference-point to boundary, line-specification
(so can
                  specify boundary as being between two fixes)  -->
<!--      added trigger element ""      -->
<!--      added ATL and IRQ to FixNames      -->
<!--      added SectorNames Georgia High, Dublin      -->
<!--      expanded element handoff to include children elements Sector,
initial-handoff, final-handoff -->
<!--      added maxOccurs='unbounded' to consequence element, move-to-
alt      -->
<!--      added maxOccurs='unbounded' to consequence element, initial-
handoff      -->
<!--      changed element name of second reference-point to other-point
-->
<!--      added "one-of" choice under "move-to-alt" consequence -->
<!--      added "one-of" choice to AircraftType 10-1-2003 -->
<!--      added "radial-specification" to boundary element 12-4-2003   --
>
<!--      added "bearingType" to for "radial-specification" element 12-4-
2003      -->
<!--      added explicit MultiLineString type, commenting out include of
tgcCommon.xsd 12-4-2003      -->
<!--      deleted cross-alt as a consequence element; it became a
qualifier to cross 12-4-2003      -->

<xsd:schema xmlns:xsd='http://www.w3.org/2001/XMLSchema'>
<!-- <xsd:include schemaLocation="file:///C:/enrt_xml/tgcCommon.xsd"/>
-->

<xsd:annotation>
  <xsd:documentation>
    ATC Directives about En-Route Trajectories
  </xsd:documentation>
</xsd:annotation>

<xsd:element name='ATC_Directives'>
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref='rule' maxOccurs='unbounded' />
      <xsd:element ref='rule_issues' minOccurs='0'
maxOccurs='unbounded' />
    </xsd:sequence>
  </xsd:complexType>
  <xsd:key name="RuleNo">

```

```

<xsd:selector xpath=".//rule"/>
<xsd:field xpath="@id"/>
</xsd:key>
<xsd:keyref name="RuleNoRef" refer="RuleNo">
    <xsd:selector xpath=".//rule_issues"/>
    <xsd:field xpath="@id"/>
</xsd:keyref>
</xsd:element>

<xsd:element name='rule'>
    <xsd:complexType>
        <xsd:sequence>
            <xsd:element ref='doc-ref'/>
            <xsd:element ref='trigger' maxOccurs='unbounded' />
            <xsd:element ref='consequence' maxOccurs='unbounded' />
            <xsd:element name="comment" type="MultiLineStringType"
minOccurs="0" />
        </xsd:sequence>
        <xsd:attribute name='id' type='xsd:integer' use='required' />
    </xsd:complexType>
</xsd:element>

<xsd:element name='doc-ref'>
    <xsd:complexType>
        <xsd:sequence>
            <xsd:element name='docref-id' type="xsd:string"/>
            <xsd:element name='docref-text' type="xsd:string"
maxOccurs='unbounded' />
            <xsd:element name='doc-text' type="MultiLineStringType"/>
            <xsd:element name='sector' type="SectorName"/>
            <xsd:element name='area' type="xsd:integer"/>
            <xsd:element name='center' type="CenterName"/>
        </xsd:sequence>
    </xsd:complexType>
</xsd:element>

<xsd:element name='trigger'>
    <xsd:complexType>
        <xsd:choice maxOccurs='unbounded'>
            <xsd:element ref='aircraft-type' />
            <xsd:element name='in-sector' type="SectorName" />
            <xsd:element name='above-sector' type="SectorName" />
            <xsd:element name='inbound-to-apt' type="AirportType" />
            <xsd:element name='departing-from-apt' type="AirportType" />
            <xsd:element name='AOA-alt' type="AltitudeType" />
            <xsd:element name='AOB-alt' type="AltitudeType" />
            <xsd:element name='from-sector' type="SectorName" />
            <xsd:element name='to-sector' type="SectorName" />
            <xsd:element name='via-sector' type="SectorName" />
            <xsd:element ref='cross' />
            <xsd:element ref='at' />
            <xsd:element name='on-Vroute' type="VRouteNames" />
            <xsd:element ref='flight-plan-request' />
            <xsd:element name='transition' type="FixName" />
            <xsd:element name="direction-of-flight" type="geo-relation-type" />
        </xsd:choice>
    </xsd:complexType>
</xsd:element>

```

```
</xsd:element>

<xsd:element name="aircraft-type">
  <xsd:complexType>
    <xsd:choice>
      <xsd:element name="name" type="AircraftType"/>
      <xsd:element name="one-of">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="name" maxOccurs="unbounded"
type="AircraftType"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:choice>
  </xsd:complexType>
</xsd:element>

<xsd:simpleType name="AircraftType">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="Turbojet"/>
    <xsd:enumeration value="Turboprop"/>
  </xsd:restriction>
</xsd:simpleType>

<xsd:complexType name="AirportType">
  <xsd:choice minOccurs="1" maxOccurs="1">
    <xsd:element name="airport-group" type="AirportGroupType"/>
    <xsd:element name="airport-list">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element ref="airport-name" minOccurs="2"
maxOccurs="unbounded"/>
        </xsd:sequence>
      </xsd:complexType>
    </xsd:element>
    <xsd:element ref="airport-name"/>
  </xsd:choice>
</xsd:complexType>

<xsd:simpleType name="AirportGroupType">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="Nashville Terminal Area"/>
    <xsd:enumeration value="Atlanta Terminal Area"/>
  </xsd:restriction>
</xsd:simpleType>

<xsd:element name="airport-name">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="CLT"/>
      <xsd:enumeration value="LYH"/>
      <xsd:enumeration value="GSO"/>
      <xsd:enumeration value="INT"/>
      <xsd:enumeration value="ATL"/>
      <xsd:enumeration value="BNA"/>
      <xsd:enumeration value="MQY"/>
```

```

<xsd:enumeration value="JWN"/>
<xsd:enumeration value="MBT"/>
<xsd:enumeration value="GSP"/>
<xsd:enumeration value="GMU"/>
<xsd:enumeration value="SPA"/>
<xsd:enumeration value="GYH"/>
<xsd:enumeration value="CHA"/>
<xsd:enumeration value="GVL"/>
<xsd:enumeration value="AJR"/>
<xsd:enumeration value="TRI"/>
<xsd:enumeration value="AVL"/>
<xsd:enumeration value="WDR"/>
<xsd:enumeration value="AHN"/>
<xsd:enumeration value="19A"/>
</xsd:restriction>
</xsd:simpleType>
</xsd:element>

<xsd:simpleType name="SectorName">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="Salem"/>
        <xsd:enumeration value="Pulaski"/>
        <xsd:enumeration value="Leeon"/>
        <xsd:enumeration value="Moped"/>
        <xsd:enumeration value="Dublin"/>
        <xsd:enumeration value="Spartanburg"/>
        <xsd:enumeration value="Spartanburg High"/>
        <xsd:enumeration value="Georgia High"/>
        <xsd:enumeration value="Baden"/>
        <xsd:enumeration value="Logen"/>
        <xsd:enumeration value="Commerce"/>
        <xsd:enumeration value="Burne"/>
        <xsd:enumeration value="North Departure"/>
        <xsd:enumeration value="Lanier"/>
        <xsd:enumeration value="South Boston"/>
        <xsd:enumeration value="Macon High"/>
        <xsd:enumeration value="Macon"/>
        <xsd:enumeration value="South Departure"/>
        <xsd:enumeration value="Clark Hill"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="VRouteNames">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="V54"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="TransitionNames">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="VXV"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="AltitudeType">
    <xsd:restriction base="xsd:string">
        <xsd:pattern value="FL\d+/">
    </xsd:restriction>
</xsd:simpleType>

```

```

        <xsd:pattern value="\d+, \d{3} feet"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="CenterName">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="ZTL"/>
        <xsd:enumeration value="ZNY"/>
        <xsd:enumeration value="ZDC"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:element name="at">
    <xsd:complexType>
        <xsd:choice maxOccurs="1" minOccurs="1">
            <xsd:element ref="boundary"/>
            <xsd:element name="reference-point" type="FixName"/>
            <xsd:element ref="region-specification"/>
        </xsd:choice>
    </xsd:complexType>
</xsd:element>

<xsd:element name="boundary">
    <xsd:complexType>
        <xsd:sequence>
            <xsd:choice maxOccurs="1" minOccurs="1">
                <xsd:element name="sector-boundary">
                    <xsd:complexType>
                        <xsd:sequence>
                            <xsd:element name="from-sector" type="SectorName"/>
                            <xsd:element name="to-sector" type="SectorName"/>
                        </xsd:sequence>
                    </xsd:complexType>
                </xsd:element>
            <xsd:element name="center-boundary">
                <xsd:complexType>
                    <xsd:sequence>
                        <xsd:element name="from-center" type="CenterName"/>
                        <xsd:element name="to-center" type="CenterName"/>
                    </xsd:sequence>
                </xsd:complexType>
            </xsd:element>
        <xsd:element name="line-specification">
            <xsd:complexType>
                <xsd:sequence>
                    <xsd:element name="reference-point" type="FixName"/>
                    <xsd:choice maxOccurs="unbounded" minOccurs="1">
                        <xsd:element name="geo-relation-to" type="geo-
relation-type"/>
                        <xsd:element name="distance-from"
type="distanceType"/>
                            <xsd:element name="other-point" type="FixName"/>
                        </xsd:choice>
                    </xsd:sequence>
                </xsd:complexType>
            </xsd:element>
        <xsd:element name="arc-specification">

```

```

<xsd:complexType>
  <xsd:sequence>
    <xsd:element name="reference-point" type="FixName"/>
    <xsd:element name="distance-from" type="distanceType"/>
  </xsd:sequence>
</xsd:complexType>
</xsd:element>
<xsd:element name="radial-specification">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="reference-point" type="FixName"/>
      <xsd:element name="bearing" type="bearingType"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
<xsd:element name="VRoute" type="VRouteNames"/>
</xsd:choice>
</xsd:sequence>
</xsd:complexType>
</xsd:element>

<xsd:element name="region-specification">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="boundary"/>
      <xsd:element name="geo-relation-to" type="geo-relation-type"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>

<xsd:simpleType name="FixName">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="HRS"/>
    <xsd:enumeration value="SOT"/>
    <xsd:enumeration value="ODF"/>
    <xsd:enumeration value="SPA"/>
    <xsd:enumeration value="HMV"/>
    <xsd:enumeration value="VXV"/>
    <xsd:enumeration value="JMV"/>
    <xsd:enumeration value="macey"/>
    <xsd:enumeration value="ATL"/>
    <xsd:enumeration value="IRQ"/>
  </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="geo-relation-type">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="north"/>
    <xsd:enumeration value="south"/>
    <xsd:enumeration value="east"/>
    <xsd:enumeration value="west"/>
    <xsd:enumeration value="northwest"/>
    <xsd:enumeration value="northeast"/>
    <xsd:enumeration value="southeast"/>
    <xsd:enumeration value="southwest"/>
  </xsd:restriction>
</xsd:simpleType>

```

```

<xsd:element name="flight-plan-request">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="altitude" type="AltitudeType"/>
      <xsd:element name="alt-relation-to" type="alt-relation-type"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>

<xsd:simpleType name="alt-relation-type">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="above"/>
    <xsd:enumeration value="at or above"/>
    <xsd:enumeration value="at"/>
    <xsd:enumeration value="at or below"/>
    <xsd:enumeration value="below"/>
    <xsd:enumeration value="aoa"/>
    <xsd:enumeration value="aob"/>
  </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="distanceType">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="\d+/">
    <xsd:pattern value="\d+ nm"/>
    <xsd:pattern value="\d+ DME"/>
    <xsd:pattern value="\d+ miles"/>
    <xsd:pattern value="\d+, \d{3} feet"/>
  </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="bearingType">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="\d+/">
  </xsd:restriction>
</xsd:simpleType>

<xsd:element name='consequence'>
  <xsd:complexType>
    <xsd:choice maxOccurs='unbounded'>
      <xsd:element ref='cross'/>
      <xsd:element name='cleared-via' type="xsd:string"/>
      <xsd:element ref='move-to-alt'/>
      <xsd:element ref='heading'/>
      <xsd:element ref='handoff'/>
      <xsd:element name='transition' type="FixName"/>
    </xsd:choice>
  </xsd:complexType>
</xsd:element>

<xsd:element name="cross">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="boundary"/>
      <xsd:choice maxOccurs="unbounded" minOccurs="0">
        <xsd:element name='cross-alt' type="AltitudeType"/>

```

Encoding en-route trajectory ATC Directives in XML with XML Schema

```
<xsd:element name='AOA-alt' type="AltitudeType"/>
<xsd:element name='AOB-alt' type="AltitudeType"/>
</xsd:choice>
</xsd:sequence>
</xsd:complexType>
</xsd:element>

<xsd:element name="heading">
<xsd:complexType>
<xsd:sequence>
<xsd:element name="cross">
<xsd:complexType>
<xsd:sequence>
<xsd:element ref="boundary"/>
</xsd:sequence>
</xsd:complexType>
</xsd:element>
<xsd:element name='prior-to'>
<xsd:complexType>
<xsd:sequence>
<xsd:element ref="boundary"/>
</xsd:sequence>
</xsd:complexType>
</xsd:element>
</xsd:sequence>
</xsd:complexType>
</xsd:element>

<xsd:element name="move-to-alt">
<xsd:complexType>
<xsd:choice>
<xsd:element name="altitude" type="AltitudeType"/>
<xsd:element name="one-of">
<xsd:complexType>
<xsd:sequence>
<xsd:element name="altitude" type="AltitudeType"
maxOccurs="unbounded"/>
</xsd:sequence>
</xsd:complexType>
</xsd:element>
</xsd:choice>
</xsd:complexType>
</xsd:element>

<xsd:element name="handoff">
<xsd:complexType>
<xsd:choice maxOccurs="unbounded">
<xsd:element name="sector" type="SectorName"/>
<xsd:element name="initial-handoff" type="SectorName"
maxOccurs='unbounded' />
<xsd:element name="final-handoff" type="SectorName"/>
</xsd:choice>
</xsd:complexType>
</xsd:element>

<!-- -->
<xsd:element name='rule_issues'>
```

Encoding en-route trajectory ATC Directives in XML with XML Schema

```
<xsd:complexType>
  <xsd:sequence>
    <xsd:element name='comment' type='MultiLineStringType' />
  </xsd:sequence>
  <xsd:attribute name='id' type='xsd:integer' use='required' />
</xsd:complexType>
</xsd:element>

<xsd:simpleType name="MultiLineStringType">
  <xsd:annotation id="MultiLineStringType.annotation">
    <xsd:appinfo xml:lang="en">
      <ToolTip>
        Multiple Line String
      </ToolTip>
    </xsd:appinfo>
  </xsd:annotation>
  <xsd:restriction base="xsd:string"/>
</xsd:simpleType>

</xsd:schema>

<!--
ZAB Albuquerque Air Route Traffic Control Center (ARTCC)
ZAU Chicago Air Route Traffic Control Center (ARTCC)
ZBW Boston Air Route Traffic Control Center (ARTCC)
ZDC Washington Air Route Traffic Control Center (ARTCC)
ZFW Dallas-Ft Worth Air Route Traffic Control Center (ARTCC)
ZHU Houston Air Route Traffic Control Center (ARTCC)
ZID Indianapolis Air Route Traffic Control Center (ARTCC)
ZJX Jacksonville Air Route Traffic Control Center (ARTCC)
ZKC Kansas City Air Route Traffic Control Center (ARTCC)
ZLA Los Angeles Air Route Traffic Control Center (ARTCC)
ZLC Salt Lake City Air Route Traffic Control Center (ARTCC)
ZMA Miami Air Route Traffic Control Center (ARTCC)
ZME Memphis Air Route Traffic Control Center (ARTCC)
ZMP Minneapolis Air Route Traffic Control Center (ARTCC)
ZNY New York Air Route Traffic Control Center (ARTCC)
ZOA Oakland Air Route Traffic Control Center (ARTCC)
ZOB Cleveland Air Route Traffic Control Center (ARTCC)
ZSE Seattle Air Route Traffic Control Center (ARTCC)
ZTL Atlanta Air Route Traffic Control Center (ARTCC)
-->
```

Appendix C: Air Route Traffic Control Centers

ZAB Albuquerque Air Route Traffic Control Center (ARTCC)

ZAN Anchorage Air Route Traffic Control Center (ARTCC)

ZAU Chicago Air Route Traffic Control Center (ARTCC)

ZBW Boston Air Route Traffic Control Center (ARTCC)

ZDC Washington Air Route Traffic Control Center (ARTCC)

ZDV Denver Air Route Traffic Control Center (ARTCC)

ZFW Dallas-Ft Worth Air Route Traffic Control Center (ARTCC)

ZHU Houston Air Route Traffic Control Center (ARTCC)

ZID Indianapolis Air Route Traffic Control Center (ARTCC)

ZJX Jacksonville Air Route Traffic Control Center (ARTCC)

ZKC Kansas City Air Route Traffic Control Center (ARTCC)

ZLA Los Angeles Air Route Traffic Control Center (ARTCC)

ZLC Salt Lake City Air Route Traffic Control Center (ARTCC)

ZMA Miami Air Route Traffic Control Center (ARTCC)

ZME Memphis Air Route Traffic Control Center (ARTCC)

ZMP Minneapolis Air Route Traffic Control Center (ARTCC)

ZNY New York Air Route Traffic Control Center (ARTCC)

ZOA Oakland Air Route Traffic Control Center (ARTCC)

ZOB Cleveland Air Route Traffic Control Center (ARTCC)

ZSE Seattle Air Route Traffic Control Center (ARTCC)

ZTL Atlanta Air Route Traffic Control Center (ARTCC)